**Big Data to Enable Global Disruption of the Grapevine-powered Industries**

# D5.1 - Interactive Visualisation Components

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| **RESPONSIBLE AUTHOR** | Katrien Verbert (KU Leuven) |

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| **PROJECT WEBSITE** | http://www.bigdatagrapes.eu/ |
| **COORDINATOR** | Nikos Manouselis |
| **ADDRESS** | 110 Pentelis Str., Marousi, GR15126, Greece |
| **REPLY TO** | nikosm@agroknow.com |
| **PHONE** | +30 210 6897 905 |
| **EU PROJECT OFFICER** | Ms. Annamária Nagy |
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| **RESPONSIBLE AUTHOR** | Katrien Verbert (KU Leuven) |
| **REPLY TO** | katrien.verbert@cs.kuleuven.be |
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| **AUTHORS (PARTNER)** | Nyi-Nyi Htun (KU Leuven), Francisco Gutierrez (KU Leuven), Diego Rojo (KU Leuven), Katrien Verbert (KU Leuven), Panagis Katsivelis-Perakis (Agroknow) |
| **CONTRIBUTORS** | Zervas Panagiotis (Agroknow), Timotheos Lanitis (Agroknow), Papakonstantinou Michalis (Agroknow) |
| **REVIEWER** | Nikos Manouselis (Agroknow) |

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| PARTICIPANTS | | CONTACT |
|---|---|---|
| Agroknow IKE<br>(Agroknow, Greece) | | Nikos Manouselis<br>Email: nikosm@agroknow.com |
| Ontotext AD<br>(ONTOTEXT, Bulgaria) | | Todor Primov<br>Email: todor.primov@ontotext.com |
| Consiglio Nazionale Delle Richerche<br>(CNR, Italy) | | Raffaele Perego<br>Email: raffaele.perego@isti.cnr.it |
| Katholieke Universiteit Leuven<br>(KULeuven, Belgium) | | Katrien Verbert<br>Email: katrien.verbert@cs.kuleuven.be |
| Geocledian GmbH<br>(GEOCLEDIAN Germany) | | Stefan Scherer<br>Email: stefan.scherer@geocledian.com |
| Institut National de la Recherché Agronomique<br>(INRA, France) | | Pascal Neveu<br>Email: pascal.neveu@inra.fr |
| Agricultural University of Athens<br>(AUA, Greece) | | Katerina Biniari<br>Email: kbiniari@aua.gr |
| Abaco SpA<br>(ABACO, Italy) | | Simone Parisi<br>Email: s.parisi@abacogroup.eu |
| SYMBEEOSIS LONG LIVE LIFE S.A.<br>(Symbeeosis, Greece) | | Konstantinos Gardikis<br>Email: c.gardikis@gmail.com |

# ACRONYMS LIST

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|---|---|
| PA | Precision agriculture |
| WP | Work package |
| NDVI | Normalized difference vegetation index |
| API | Application programming interface |
| HTML | Hypertext markup language |

# EXECUTIVE SUMMARY

The first deliverable of work package 5 is to develop interactive visualisation components in order to leverage interpretation and understanding of complex data. As a starting point, a systematic review was conducted where we thoroughly analysed a total of 140 research papers and found various decision support systems and visualisation tools that have been proposed in the domain of agriculture. Based on the findings of the review, we have developed a total of six interactive visualisation components. They were designed to be flexible, reusable, responsive and interactive. In this document, we present deliverable 5.1 with an extended focus on the components.

This document is structured as follows. Chapter 1 lays out an introduction to the deliverable describing the existing work and motivations. In Chapter 2, the components are described in detail together with their development method and framework. Chapter 3 provides a user manual with instructions on how to reuse the components. This document concludes with Chapter 4 where a summary of the deliverable is underlined.

The systematic review is currently being updated following the reviews from partners. Please use the following link to see the draft manuscript and to keep track of changes: https://www.sharelatex.com/read/phvzgtxbvsry. The manuscript will be submitted to the journal of Computers and Electronics in Agriculture.

**Update:** The manuscript of the systematic review was submitted to the journal of Computers and Electronics in Agriculture in January 2019 and was published in June 2019. It is available online at https://doi.org/10.1016/j.compag.2019.05.053.

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# 1 INTRODUCTION

The volume of data available from farms has rapidly increased as the use of farm sensors, high-tech harvesters and drones is becoming more popular. Many farmers, therefore, feel overloaded by this large volume of data, and need additional tools for understanding and interpreting their data[1]. Visualisation is a powerful technique to mitigate these issues and has demonstrated its usefulness in the precision agriculture (PA) domain[2]. Visualisation is also effective at communicating uncertainty in seasonal climate prediction[3], an important task in agriculture. As Rind et al.[4] stated, visualisation provides a way to utilise "the processing power of modern computers with human cognition and visual abilities to better support analysis tasks".

The benefits of visualising complex data arise from being able to better interact and understand data by aggregating, filtering, searching or scaling down relevant information. As such, a large volume of data with potentially complex information becomes more easily consumable. Due to such benefits, visualisation tools have been widely used in various domains to assist with tasks that might otherwise require significant cognitive effort. For instance, analysis of past volcanic activities using a time series graph can uncover trends and can aid in predicting future eruption of a volcano. In the domain of agriculture, visualisation tools are being used in a number of sub-areas, including viticulture, dairy farming, wheat production, pest management, crop management, irrigation management and fertiliser management.

Under the work package 5 (WP5: leveraging data value), BigDataGrapes will develop a number of visualisation components and a trust-aware decision support system for stakeholders in the grapevine-powered industry. As a first step towards accomplishing this, we conducted a systematic review gathering an exhaustive list of decision support systems and visualisation tools that have been proposed in the domain of agriculture. We reviewed a total of 140 research papers thoroughly and presented our findings from 61 relevant papers. Results of this review have been disseminated in the journal of Computers and Electronics in Agriculture and are summarised in the followings.

We found that the majority of decision support systems in agriculture use at least one interactive visualisation technique which includes: heatmap (overlaid over geographical maps), time-series, histograms, bar chart, pie chart, radar chart, clustering, temporal pattern and cross section representations of a farm. Thus, various visualisation techniques are being used in differing areas of agriculture. Nevertheless, we discovered that the area of agricultural decision support systems still lacks the support from interactive visualisations with modern technology and uncertainty visualisations. For instance, the majority of the interfaces were designed for standalone PCs which lacks the flexibility and cross-platform support unlike web applications. Taking into account these findings, we selected a total of six most widely used visualisations to showcase in this first version of the deliverable. To provide flexibility and cross-platform support, the visualisations are developed as web components which can be easily reused in new development

[1] Ruß, G., Kruse, R., Schneider, M. and Wagner, P., 2009. Visualization of agriculture data using self-organizing maps. In *Applications and Innovations in Intelligent Systems XVI* (pp. 47-60). Springer, London.

[2] Wachowiak, M.P., Walters, D.F., Kovacs, J.M., Wachowiak-Smolikova, R. and James, A.L., 2017. Visual analytics and remote sensing imagery to support community-based research for precision agriculture in emerging areas. *Computers and Electronics in Agriculture*, *143*, pp.149-164.

[3] Frías, M.D., Iturbide, M., Manzanas, R., Bedia, J., Fernández, J., Herrera, S., Cofiño, A.S. and Gutiérrez, J.M., 2018. An R package to visualize and communicate uncertainty in seasonal climate prediction. *Environmental Modelling & Software*, *99*, pp.101-110.

[4] Rind, A., Wang, T.D., Aigner, W., Miksch, S., Wongsuphasawat, K., Plaisant, C. and Shneiderman, B., 2013. Interactive information visualization to explore and query electronic health records. *Foundations and Trends® in Human–Computer Interaction*, *5*(3), pp.207-298.

projects. All of the components have been tested in a number of popular web browsers, including: Chrome, Firefox, Opera and Safari.

Interaction also plays an important role since perception and understanding of complex data can be strongly influenced by the interactivity of a visualisation component[5]. Examples of interactive visualisation components can be found in various tools including ViPER[6], AgriSuit[7] and Geovit[8]. ViPER provides an interactive drag-and-drop interface where users can explore livestock and examine 'what-if?' scenarios. AgriSuit provides an interface to allow a customised selection of weights based on user preferences to achieve a better visualisation. Geovit provides an interactive dashboard that allows the selection of areas of interest; based on this selection users can explore valuable information about the soil, climate and hydrology in real-time. Therefore, the visualisation components we showcased in this deliverable are designed to support interactions in order to allow users to better explore and understand the data and make informed decisions.

The utility and benefits of interactive visualisations are immense. Besides, added benefits of interactivity include an increase in perception and understanding of complex data. This deliverable (D5.1), therefore, concentrates on developing interactive visualisation components. The primary aim is to develop the components that are flexible, reusable, responsive and interactive. Our systematic review highlighted the most common visualisations in agriculture, together with their use case examples. In this first version of deliverable 5.1, we have chosen to develop a total of six most common interactive visualisation components, namely: time series, bar chart, histogram, radar chart, scatter plot and heatmap-based map. We used example data to showcase the components since data from the pilot partners were unavailable at the time of development. Hence, it is important to note that the components showcased here are not yet customised using the real data from partners. In the next iteration of deliverable 5.1, we intend to use the data received from the pilot partners to customise and further improve the components and add additional components that are best suited for their requirements and use cases.

In Chapter 2, detailed descriptions of the components and development framework are presented. A user manual has also been provided in Chapter 3 describing detailed instructions on how to utilise the components.

[5] Zudilova-Seinstra, E., Adriaansen, T. and Van Liere, R., 2009. Overview of interactive visualisation. In *Trends in Interactive Visualization* (pp. 3-15). Springer, London.
[6] Oliver, D.M., Bartie, P.J., Heathwaite, A.L., Pschetz, L. and Quilliam, R.S., 2017. Design of a decision support tool for visualising E. coli risk on agricultural land using a stakeholder-driven approach. *Land Use Policy*, *66*, pp.227-234.
[7] Yalew, S.G., Van Griensven, A. and van der Zaag, P., 2016. AgriSuit: A web-based GIS-MCDA framework for agricultural land suitability assessment. *Computers and Electronics in Agriculture*, *128*, pp.1-8.
[8] Terribile, F., Bonfante, A., D'Antonio, A., De Mascellis, R., De Michele, C., Langella, G., Manna, P., Mileti, F.A., Vingiani, S. and Basile, A., 2017. A geospatial decision support system for supporting quality viticulture at the landscape scale. *Computers and Electronics in Agriculture*, *140*, pp.88-102.

# 2 COMPONENTS & DEVELOPMENT FRAMEWORK

## 2.1 COMPONENTS

The followings are the six visualisation components that have been chosen for development, namely: time-series, bar chart, histogram, radar chart, scatter plot and heatmap-based map. The components have been developed using the Charts.js library which provides a great number of prebuilt charts that can be easily customised. Building a bar chart, for example, is as simple as specifying the `type` of the chart as 'bar' (see the following lines of code):

```
var myBarChart = new Chart(ctx, {
    type: 'bar',
    data: data,
    options: options
});
```

The `data` and `options` elements respectively allow us to input the dataset and configure the chart. A detailed documentation of these elements for each chart can be found at [http://www.chartjs.org/docs/latest/charts/](http://www.chartjs.org/docs/latest/charts/).

### 2.1.1 Time series

A time series is a distribution of data points visualised in time order. It is usually presented as a sequence with successive equally spaced points in time. Figure 1 shows the time series component with example data.

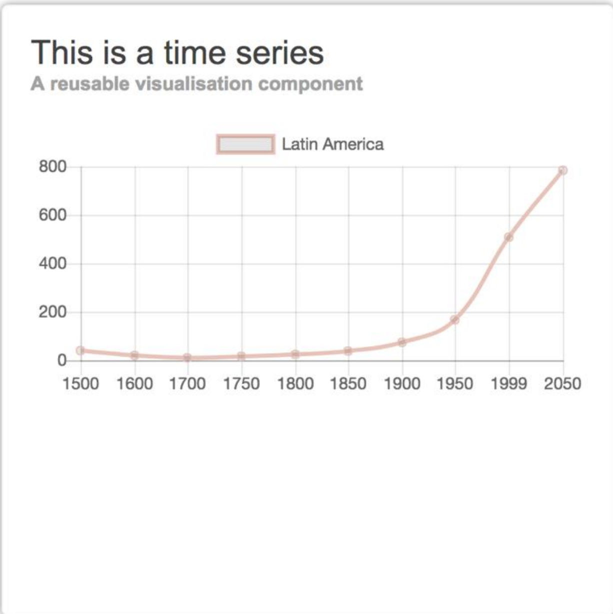



**Figure 1. Time series**

The following code snippet shows how the time series was implemented using the Charts.js library. Notice how the `type: 'line'` was specified for time series as they are similar in structure to line charts.

```
var myChart = new Chart(ctx, {
 type: 'line',
 data: {
  labels: [1500,1600,1700,1750,1800,1850,1900,1950,1999,2050],
  datasets: [{
   data: [40,20,10,16,24,38,74,167,508,784],
   label: "Latin America",
   borderColor: "#e8c3b9",
   fill: false
  }]
 },
  options: {
   legend: {
   },
   scales: {
    yAxes: [{
     ticks: {
      beginAtZero:true
     }
    }]
   }
  }
 });
```

### 2.1.2 Bar chart

A bar chart shows comparisons among discrete categories. One axis of the chart shows the specific categories being compared, and the other axis represents a measured value. Bar charts present bars clustered in groups of more than one, showing the values of more than one measured variable. In the following example, Figure 2, a comparison between six variables, red, blue, yellow, green, purple and orange can be observed.

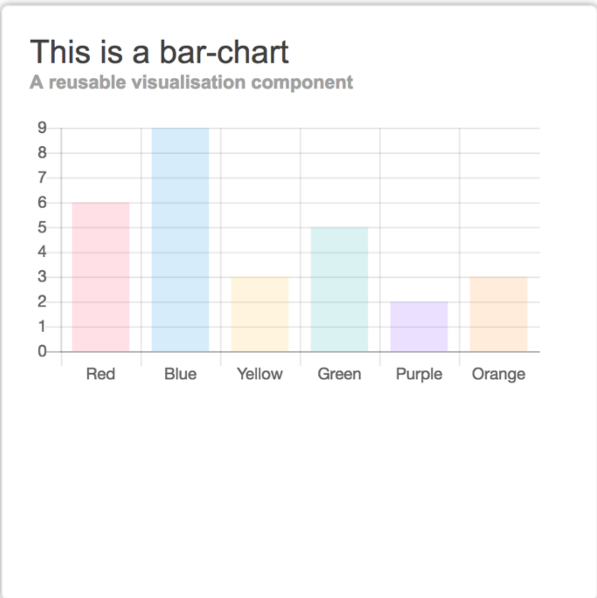



Figure 2. Bar chart

The following code snippet shows how the bar chart was implemented.

```
var myChart = new Chart(ctx, {
  type: 'bar',
  data: {
    labels: ["Red", "Blue", "Yellow", "Green", "Purple", "Orange"],
    datasets: [{
      data: [6, 9, 3, 5, 2, 3],
      backgroundColor: [
        'rgba(255, 99, 132, 0.2)',
        'rgba(54, 162, 235, 0.2)',
        'rgba(255, 206, 86, 0.2)',
        'rgba(75, 192, 192, 0.2)',
        'rgba(153, 102, 255, 0.2)',
        'rgba(255, 159, 64, 0.2)'
      ],
      borderColor: [
        'rgba(255,99,132,1)',
        'rgba(54, 162, 235, 1)',
        'rgba(255, 206, 86, 1)',
        'rgba(75, 192, 192, 1)',
        'rgba(153, 102, 255, 1)',
        'rgba(255, 159, 64, 1)'
      ]
    }]
  },
  options: {
    legend: {
      display: false
    },
    scales: {
      yAxes: [{
        ticks: {
          beginAtZero:true
        }
      }]
    }
  }
});
```

### 2.1.3 Histogram

A histogram is a representation of the distribution of numerical data. It differs from a bar chart, in that a bar chart represents categorical variables, whereas in a histogram each column represents a continuous quantitative variable. Figure 3 shows the histogram component with simulated data.

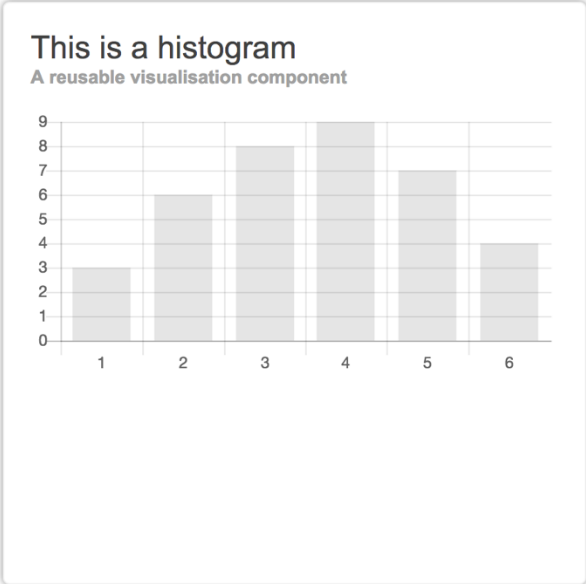



Figure 3. Histogram

The following code snippet shows how the histogram was implemented. Notice how the `type: 'bar'` was specified for histogram as they are similar in structure to bar charts.

```
var myChart = new Chart(ctx, {
  type: 'bar',
  data: {
    labels: ["1", "2", "3", "4", "5", "6"],
    datasets: [{
      data: [3, 6, 8, 9, 7, 4],
    }]
  },
  options: {
    legend: {
      display: false
    },
    scales: {
      yAxes: [{
        ticks: {
          beginAtZero:true
        }
      }]
    }
  }
});
```

### 2.1.4 Radar chart

A radar chart is a visual representation of multivariate data in the form of a two-dimensional chart of three or more quantitative variables represented on axes starting from the same point. The following example, Figure 4, shows the radar chart component with simulated data across four dimensions (axes).

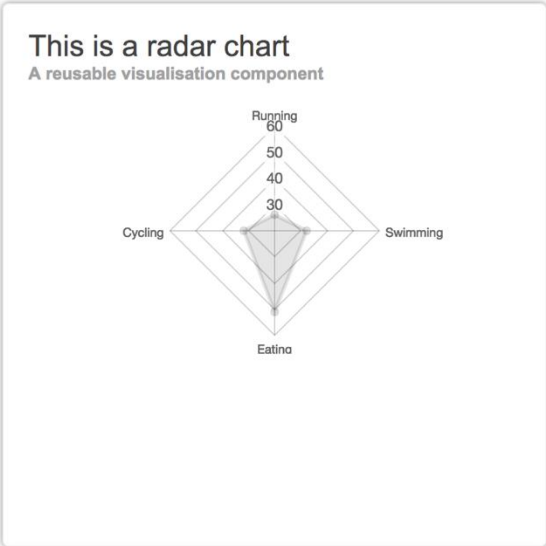



**Figure 4. Radar chart**

The following code snippet shows how the radar chart was implemented. Note that properties such as backgroundColor, borderColor and pointBackgroundColor can be used to set a different colour for each dimension (see [http://www.chartjs.org/docs/latest/charts/radar.html](http://www.chartjs.org/docs/latest/charts/radar.html) for detail).

```
var myChart = new Chart(ctx, {
  type: 'radar',
  data: {
    labels: ['Running', 'Swimming', 'Eating', 'Cycling'],
    datasets: [{
      data: [26, 32, 51, 32]
    }]
  },
  options: {
    legend: {
      display: false
    }
  }
});
```

### 2.1.5 Scatter plot

A scatter plot is a two-dimensional data visualization that uses dots to represent the values obtained for two different variables - one plotted along the x-axis and the other plotted along the y-axis. This component can be seen in Figure 5 with simulated data.

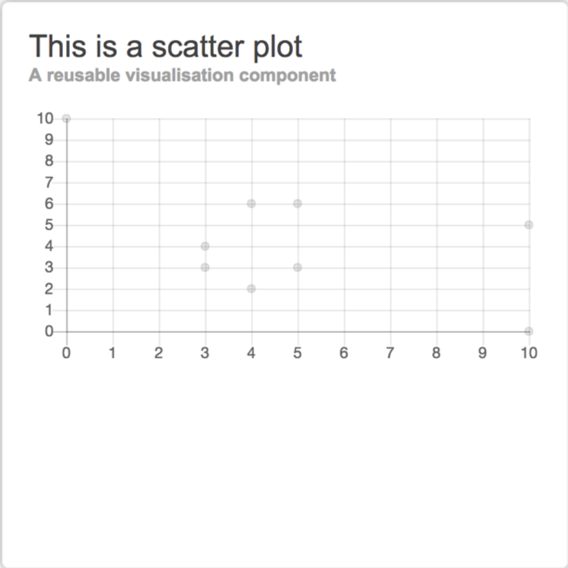



Figure 5. Scatter plot

The following code snippet shows how the scatter plot was implemented.

```
var myChart = new Chart(ctx, {
  type: 'scatter',
  data: {
    datasets: [{
      label: 'Scatter Dataset',
      data: [{
        x: 10,
        y: 0
      }, {
        x: 0,
        y: 10
      }, {
        x: 10,
        y: 5
      }, {
        x: 4,
        y: 6
      }, {
        x: 3,
        y: 3
      }, {
        x: 3,
        y: 4
      }, {
        x: 4,
        y: 2
      }, {
        x: 5,
        y: 3
      }, {
        x: 5,
        y: 6
      }]
    }]
  },
  options: {
```

```
    legend: {
      display: false
    },
    scales: {
      yAxes: [{
        ticks: {
          beginAtZero:true
        }
      }]
    }
  }
});
```

### 2.1.6 Heatmap-based Map

Heatmaps are graphical representations of data where individual values contained in an area of interest are represented with various spectrum of colours. In agricultural data visualisation (e.g. NDVI), heatmaps are overlaid on top of a geographical map. Figure 6 shows the heatmap component with simulated data.

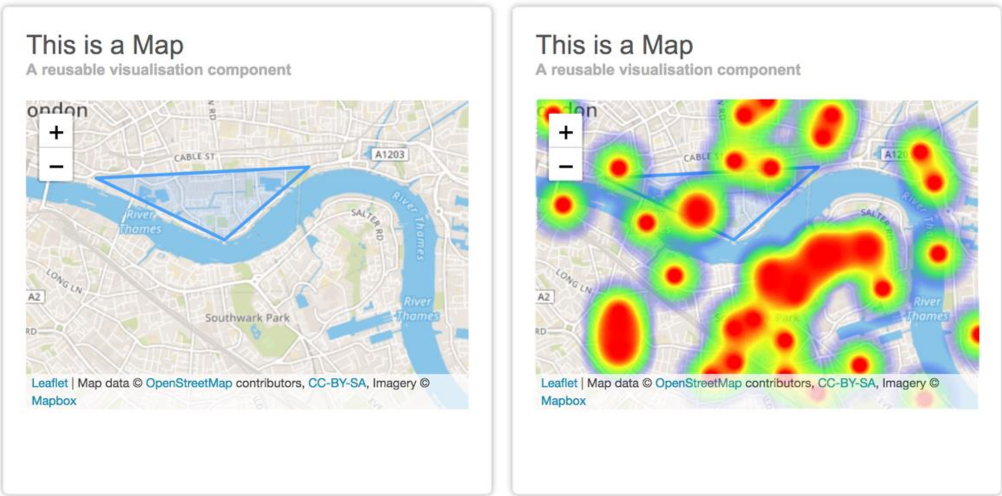



**Figure 6. Heatmap**

The following code snippet shows how the heatmap component was implemented. The Mapbox API was used to get a map layer. The boundaries on the map were also created with the Mapbox API. A heatmap overlay can then be inserted on top of the map using the same API.

```
var mymap = L.map(this.shadowRoot.querySelector("#mapid")).setView([51.505, -0.09], 13);
  L.tileLayer('https://api.tiles.mapbox.com/v4/{id}/{z}/{x}/{y}.png?access_token={accessToken}', {
    attribution: 'Map data &copy; <a href="https://www.openstreetmap.org/">OpenStreetMap</a>
contributors, <a href="https://creativecommons.org/licenses/by-sa/2.0/">CC-BY-SA</a>, Imagery © <a
href="https://www.mapbox.com/">Mapbox</a>',
    maxZoom: 18,
    id: 'mapbox.streets',
    accessToken:
'pk.eyJ1IjoiZnJhbmNpc2NvZ2h6IiwiYSI6ImNpbnV1Z3J4eTAwb3R2c2tscXgwMWs2eHEifQ.OrlG9so4Yih
IM4ccw59cHw'
}).addTo(mymap);

var polygon = L.polygon([
    [51.509, -0.08],
```

```
    [51.503, -0.06],
    [51.51, -0.047]
]).addTo(mymap);
```

## 2.2 DEVELOPMENT FRAMEWORK

We used the Polymer[9] framework to create the components. Polymer provides a JavaScript library to develop responsive web applications with custom Web Components[10] that are easily reusable. Using a component built within the Polymer framework is as simple as importing its definition, and then using it like any other HTML elements. For example, the following lines of code show a simple method to import a prebuilt paper-checkbox component and reuse the <paper-checkbox> element in HTML:

**Demo:** https://jsfiddle.net/6hgk127e/1/

```
<!-- Import a component -->
<script src="https://unpkg.com/@polymer/paper-checkbox@next/paper-checkbox.js?module"
type="module" ></script>

<!-- Use it like any other HTML element -->
<paper-checkbox>Web Components!</paper-checkbox>
```

Similarly, to reuse our visualisation components, the following codes can be deployed. Notice the simplicity and scalability of the components due to the Polymer framework.

```
<!-- Import the components -->
<script src="../bar-chart.js"></script>
<script src="../histogram.js"></script>
<script src="../scatterplot.js"></script>
<script src="../radar-chart.js"></script>
<script src="../time-series.js"></script>
<script src="../map.js"></script>

<!-- Call the components with the following HTML tags -->
<vis-barchart></vis-barchart>
<vis-histogram></vis-histogram>
<vis-radar></vis-radar>
<vis-scatter></vis-scatter>
<vis-series></vis-series>
<vis-map></vis-map>
```

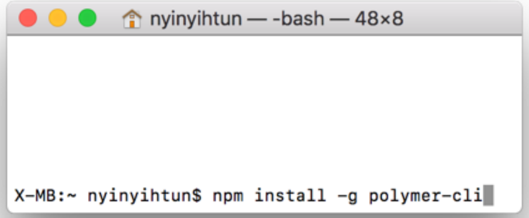
[9] https://www.polymer-project.org/

[10] https://www.webcomponents.org/

# 3 USER MANUAL

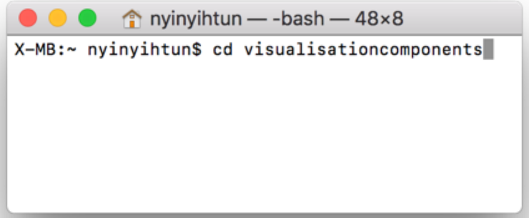
The codes of the components have been uploaded to github: https://github.com/BigDataGrapes-EU/visualisationcomponents. Please follow the following steps to utilise the components.

1. Install npm and node.js from https://www.npmjs.com/get-npm
2. Install the Polymer-CLI: `npm install -g polymer-cli`

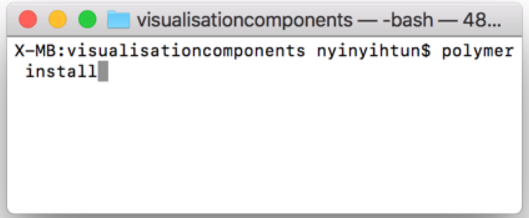



3. Download or clone the project: `git clone https://github.com/BigDataGrapes-EU/visualisationcomponents.git`

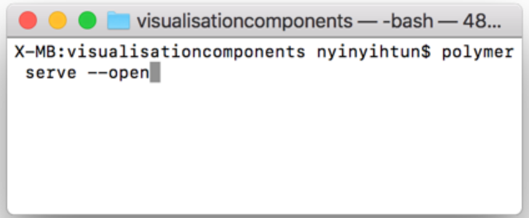

4. Navigate to the cloned/downloaded folder: `cd visualisationcomponents`




5. Install Polymer dependencies: `polymer install`




6. Serve Polymer: polymer serve --open



# 4 CONCLUSIONS

In this document, we presented deliverable 5.1, interactive visualisation components, produced under work package 5. Emanating from a systematic review of previous research work in precision agriculture, a total of six most common visualisations have been designed, namely: time series, bar chart, histogram, radar chart, scatter plot and heatmap-based map. It should be noted that during the time of development, data and requirements for pilot partners have not yet been fixed. Thus, the components showcased in this deliverable are not customised using the real data from partners. Nevertheless, to ensure that the components can be easily reused by partners in the future, we followed the Polymer framework which provides a JavaScript library for building web applications with custom Web Components. Detailed explanations of the development method and framework have been presented in Chapter 2.1 and 2.2 respectively. We also provided sample codes for each of the components highlighting their usability. All of the codes have been published at the github repository of BigDataGrapes (https://github.com/BigDataGrapes-EU/visualisationcomponents). A manual has been provided in Chapter 3 with steps for obtaining the codes and serving the components.

For the next deliverable, D5.2, we will soon begin developing a modular trust-aware decision support system which will provide much needed assistance for various decision-making scenarios in the grapevine-powered industry. The initial system will be delivered by M12 as part of deliverable D5.2. This system and the visualisation components presented in this document will be refined further to support upcoming use cases from partners which will further provide solutions for data analytic requirements. To be specific, in the next iteration of deliverable 5.1, we intend to use the data received from the pilot partners to customise and further improve the components and add additional components that are best suited for their requirements and use cases.